

# OMNO2e Data Product Readme File

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## 1 Introduction

**OMNO2e** is a daily, gridded data product, where each file is produced from one day's worth of NO<sub>2</sub> measurements made by the Ozone Monitoring Instrument (OMI) aboard the EOS-Aura spacecraft. Aura was launched July 15, 2004, and OMI operations began on October 1, 2004. The data are filled into a grid with a horizontal resolution of  $0.25^\circ \times 0.25^\circ$  in latitude and longitude. The data fields included in the product are (1) Total column NO<sub>2</sub>, in units of molecules per cm<sup>2</sup>, cloud-screened at 30%, and (2) Tropospheric column NO<sub>2</sub>, cloud-screened at 30%.

## 2 Nitrogen dioxide

Nitrogen dioxide is an important trace gas in the Earth's atmosphere. It participates in the chemistry of ozone (O<sub>3</sub>), and is itself a biological irritant. In the troposphere, NO<sub>2</sub> contributes to the formation of ozone, while in the stratosphere, it can contribute to ozone depletion. The term "NO<sub>x</sub>" refers to the total concentration of NO<sub>2</sub> and nitrogen oxide (NO). The two NO<sub>x</sub> molecules interconvert, with the quasi-steady-state concentrations of each largely determined by photochemistry. Both NO<sub>x</sub> species are produced in combustion processes, and, to a lesser extent, in lightning. Its production in combustion makes NO<sub>x</sub> a marker of industrial activity (including fossil-fuel-based power generation, transportation, and concrete manufacture) as well as other human activities, such as agricultural biomass burning.

Because of the spectral ranges over which NO<sub>2</sub> absorbs light, with an absorption band in the visible region of the electromagnetic spectrum ( $\sim 405$  nm to 465 nm) (accounting for its perceptible reddish-brown color in the air on polluted days), it turns out that remote sensing of NO<sub>2</sub> is easy. Unfortunately, NO has no convenient-to-measure absorption bands.

### 3 The Ozone Monitoring Instrument (OMI)

The Ozone Monitoring Instrument is one of four atmospheric remote sensing instruments aboard NASA's EOS-Aura satellite. Aura is in a polar, sun-synchronous orbit with a local equator crossing time at the ascending node of about 13h45. Aura is a member of the "A-Train" formation of satellites, which makes it convenient to study collocated measurements made by various instruments on various other A-Train satellites. OMI has a swath that extends  $\pm 53^\circ$  to either side of the nadir, divided into sixty fields-of-view (FOV). At nadir, the FOVs are approximately 13 km  $\times$  24 km (along-track and cross-track), while the far-off-nadir FOVs are considerably larger. The width of the OMI swath permits nearly full global coverage of the sunlit portion of the Earth in 15 orbits, traversed over a 24 hour period. In addition, in the mid- to high-latitudes, it permits multiple measurements in a day over much of the Earth's surface, taken about 100 minutes apart (the orbital period).

OMI directly makes measurements of the solar backscattered radiances from the Earth's atmosphere and surface. It also makes daily measurements of the solar irradiance. The ratio of the radiance to the irradiance at a given wavelength is a function of the amount of light that is scattered and absorbed in the atmosphere, and reflected from the surface. Laboratory measurements of the absorption cross sections of molecules of interest, as a function of wavelength, taken together with OMI's measurements of radiance and irradiance is the basis of the process of retrieval of the vertical column densities (molecules per square cm). These calculations are done to produce a number of Level-2 data products, in which vertical column densities of numerous molecular species are retrieved on an FOV-by-FOV basis. The data product containing these retrievals is called OMNO2. The OMNO2 data product, which is a Level-2 product, is the input to the programs that produce the Level-3e product, OMNO2e.

### 4 OMNO2e

The OMNO2e data product, which is the subject of this document, consists of one file per calendar day. The days begin and end at midnight, Coordinated Universal Time (UTC), when the Satellite is near the International Date Line. (Note: UTC is very close to Greenwich Mean Time, GMT.) Each file is an HDF-EOS Version 5 (HE5) file.

#### 4.1 File naming convention

The OMNO2e file name has the form:

OMI-Aura\_L3-OMNO2e\_<datestamp>\_v003-<processing-datestamp>.he5

The fragment <datestamp> indicates the date the data were taken, and has the form `yyyymmdd` (e.g. 2005m0215).

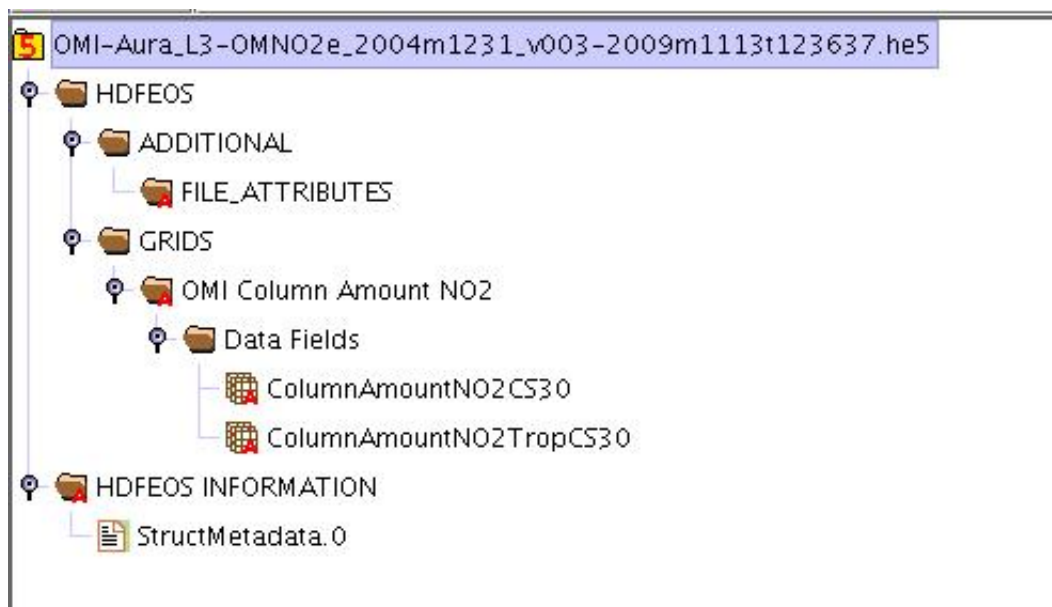
The fragment <processing-datestamp> indicates the date and time the OMNO2e file was created by the OMNO2e software. The processing-datestamp has the form `yyyymmddthhmmss`

(e.g. 2005m1227t142533).

Note that there is no accompanying metadata (.met) file.

## 4.2 File structure

The OMNO2e file is an HDF-EOS Version 5 (HE5) file, and meets the structural requirements of such files. The logical structure of the file is summarized in the following diagram:



## 4.3 Data fields

As seen in Section 4.2, there are two data grids in the file:

Name	Contents
ColumnAmountNO2CS30	Total NO <sub>2</sub> column, cloud screened at 30%
ColumnAmountNO2TropCS30	Tropospheric NO <sub>2</sub> column, cloud screened at 30%

The quantities indicated are the *visible* NO<sub>2</sub>. In the presence of any clouds, the NO<sub>2</sub> amount that is used is the amount of NO<sub>2</sub> above the cloud. Since the cloud screening threshold is 30%, this should not introduce much bias in the calculated values. It is important to know that the presence of significant (> 30%) geometric cloud fraction, there may be no usable data, and the grid cells are assigned a fill value. (See Section 4.5.) In no event is any assumed “below cloud” NO<sub>2</sub> column (sometimes called a “ghost column”) included in the calculation.

Please note that the screening criterion is applied to the estimated effective geometric cloud fraction that comes from the OMI O<sub>2</sub>O<sub>2</sub> cloud product, OMCLDO2, and *not* the cloud radiance fraction.

Each of the data grids is an array of real numbers, with dimensions (1440,720), covering, respectively, 360° of longitude and 180° of latitude in increments of 0.25° in both dimensions. The first element (1,1) corresponds to a cell whose left-hand edge is at longitude −180°, and whose bottom edge is at latitude −90°.

Each cell of each data grid contains a number that is either a weighted average of OMI FOVs that overlap that cell (Section 4.4), or a fill value (Section 4.5).

#### 4.4 Weighted average values

Each grid cell containing valid data is a weighted average of NO<sub>2</sub> column amounts belonging to all the FOVs that completely or partially overlap the cell. If no FOVs contain valid data, or if none meet the cloud screening threshold, then the cell is assigned a fill value (Section 4.5).

We now turn to describe the weighting scheme. Each of the two grids, *ColumnAmountNO2CS30* and *ColumnAmountNO2TropCS30* corresponds to the retrieved values of total column and tropospheric column NO<sub>2</sub> amounts in the Level-2 files OMNO2. If  $N$  OMI FOVs overlap with a certain grid cell  $G_{jk}$ , and  $X_i$  ( $i = 1, \dots, N$ ) are the values (total column or tropospheric column) and  $C_i$  is the cloud fraction for the same FOV, then each  $X_i$  is assigned a weight  $w_i$  as follows.

- If the summary flag (least significant bit of `vcdQualityFlags`), assigned by the OMNO2 algorithm, is set, then  $w_i = 0$
- If  $C_i > 0.30$ , then  $w_i = 0$
- If Aura is in the descending leg of its orbit, then  $w_i = 0$
- If the solar zenith angle  $\theta_o > 85^\circ$ , then  $w_i = 0$
- Compute a factor, based on the cloud fraction,

$$\varepsilon_i = 1.5 \times 10^{15} \cdot (1 + 3C_i)$$

- Compute a factor that gives greater weight to near-nadir FOVs,

$$E_i = 1.0 \times 10^{-16} (18.5 + (2.8 \times 10^{-4}) |f_i - 29.7|^{3.5})$$

- $w_i = (E_i \cdot \varepsilon_i)^{-2}$

where  $f_i$  is the cross-track position ( $0, \dots, 59$ ).

Finally, the grid cell value is calculated as:

$$G_{jk} = \frac{\sum_{i=1}^N w_i X_i}{\sum_{i=1}^N w_i}$$

## 4.5 Fill value

The fill value that is used in the grid is  $-2^{100}$ , or approximately  $-1.2676506 \times 10^{30}$ . This value is chosen to be a value that is unambiguously representable in binary floating-point: Its mantissa is identically zero, regardless of the number of bits in the mantissa. A value that is other than a power of 2 is potentially represented using different mantissas on different computer hardware platforms, due to different choices in the number of bits, and different roundoff schemes.

## 5 Notes about the data

There are several points one should keep in mind when using the OMNO2e data product. First, generally, the user should understand the fundamentals and limitations of the OMNO2 data product, from information provided in the OMNO2 Readme file (see Section 7).

The OMNO2e product is not a synoptic data product. That is, it does not represent the state of the atmosphere at a given moment. Instead, it is composed of 14–15 orbits of OMI data, each orbit's equator crossing time separated from the next by 100 minutes. At mid- and high-latitudes, values in the OMNO2e grid cells represent a combination of measurements, and some of those measurements may have been made 100 minutes apart. Given the short lifetime of  $\text{NO}_2$  in the atmosphere, the actual areal density may have changed over that time period.

Even within a single OMI orbit, the local solar time at the eastern and western edges of the swath may differ by about 1.5 hours. At high latitudes, this difference may be as large as 2.5 hours. The  $\text{NO}_2$  concentration can change quite a lot over this length of time.

OMI measures in the early afternoon near the Equator, and, due to its orbital inclination, somewhat later in the day in the Southern Hemisphere, and somewhat earlier in the day in the Northern Hemisphere. In urban areas, the tropospheric  $\text{NO}_2$  builds up very rapidly in the morning hours, and then tends to decrease into the late morning and early afternoon. In effect, OMI measures after the daily maximum has already occurred.

The data in the OMNO2e product have been cloud-screened at an apparent geometric cloud fraction of 30%. Relative weighting of the measurements takes into account the cloud fraction (see Section 4.4). However, the algorithm does not include any assumed  $\text{NO}_2$  below the cloud tops. In grid cells where no measurements were made that meet the cloud-screening condition, the cell is assigned a fill value. Furthermore, starting in November 2006, OMI experienced some problems, most likely attributed to a piece of thermal insulation material having got in the way of the instrument's optics, which affected the measurements made in certain cross-track positions. The most severe problems appear in measurements made in the Northern Hemisphere. This has led to streaks that parallel the satellite's ground track, where there may be only fill-values in the OMNO2e cells.

## 6 Data availability

All the OMI data products are available on the Goddard Earth Sciences Data and Information Services Center web site: <http://disc.gsfc.nasa.gov/Aura/OMI>.

The OMNO2e product is written as an HDF-EOS5 swath file. For a list of tools that read HDF-EOS5 data files, please visit this link: <http://disc.gsfc.nasa.gov/Aura/tools.shtml>.

Additional OMI NO<sub>2</sub> data products, including color maps of NO<sub>2</sub> vertical columns, are available through the Aura Validation Data Center (AVDC), <http://avdc.gsfc.nasa.gov>.

To report problems, or pose questions and comments related to the OMNO2e algorithm, data quality, and file structure, please send electronic mail to [omno2@ltpmail.gsfc.nasa.gov](mailto:omno2@ltpmail.gsfc.nasa.gov). Additional questions may be directed to the principal point of contact for OMNO2: James F. Gleason, [gleason@redwind.gsfc.nasa.gov](mailto:gleason@redwind.gsfc.nasa.gov).

## 7 Other documents

Users of the OMNO2e data product may find the following documents useful, as well.

OMI Data User's Guide	<a href="http://disc.sci.gsfc.nasa.gov/Aura/additional/documentation/README.OMI.DUG.pdf">http://disc.sci.gsfc.nasa.gov/Aura/additional/documentation/README.OMI.DUG.pdf</a>
OMNO2 Readme file	<a href="http://toms.gsfc.nasa.gov/omi/no2/OMNO2_readme.pdf">http://toms.gsfc.nasa.gov/omi/no2/OMNO2_readme.pdf</a>

## 8 Acknowledgement

When using the OMNO2e data in publications and presentations, the production of the data should be acknowledged as follows: "The OMI NO<sub>2</sub> daily gridded product was produced from the OMI NO<sub>2</sub> Level-2 Standard Product by the Atmospheric Chemistry and Dynamics branch, Code 613.3, NASA Goddard Space Flight Center, Greenbelt, MD. The Principal Investigator is Dr. James F. Gleason."

## 9 Contributors

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